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Electric Vehicles in Transportation

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Mobility and transportation are the critical means of economic growth in any nation. Transportation is the movement of people and goods across geographical distances. Transportation systems are an indispensable part of human activities. They remain the life blood of the economy of any nation, interconnecting cities, ports, and airports. Electric vehicles (EVs) are emerging as sustainable solution to environmental and transportation challenges in urban areas. The conventional gasoline cars are no longer the only options consumers have in selecting a car. To achieve a sustainable road transport system, EVs are preferred. They use electricity rather than petroleum. They have become popular in the past few years as technology has improved and countries seek to address future energy requirements. They provide environmental advantages, although they may carry a higher price tag initially. Electric vehicles have the potential to reshape the transportation sector in the United States, drastically cutting carbon emissions and clearing the way for significant climate progress. This paper provides an introduction to electric vehicles and their uses in transportation.

KEYWORDS: *electric vehicles, electric car, electric bicycle, transportation, transportation industry*

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INTRODUCTION

Climate change is a major challenge today and reducing greenhouse gas emissions (partly due to transportation activities and urban traffic) is important. With increasing concern over urban environmental pollution, fuel economy, global warming, and energy shortage, the electric vehicle has become an alternative form of transportation. Concerns about the environmental affects related to emissions from internal combustion engines has led to a renewed interest in electric vehicles. Shift in past decade highlights increasing use of electric, hybrid, and improved combustion engine vehicles. Figure 1 shows vehicles by technology type [1].

Electric vehicles (EVs) are vehicles that use an electric motor to move the vehicle. The traditional combustion engine car has been a staple of personal transportation for over a century, but as we move towards a more sustainable future, electric vehicles are emerging as a viable alternative. Electric vehicles (EVs) are no longer a futuristic concept; they are rapidly becoming a mainstream mode of transportation. They are a key technology for reducing emissions and transforming transportation. They can help improve air quality, public health, and fuel economy. Electric vehicles are more than just cars; they are a critical component of a cleaner, more sustainable, and innovative future of transportation. They are the single most important technology for decarbonizing the transport sector [2].

WHAT ARE ELECTRIC VEHICLES?

An electric vehicle (EV) is any vehicle that uses electric motors for propulsion. They use electricity stored in batteries or fuel cells to power the motor and propel the vehicle. Electric vehicles include electric cars, electric bicycles, electric trucks, electric trains, surface and underwater vessels, electric aircraft, and electric spacecraft. Electric vehicles can be classified into three categories: Hybrid electric vehicles (HEVs), Plug-in hybrid electric vehicles (PHEVs), and All-electric vehicles (EVs). All forms of electric vehicles (EVs) can help improve fuel economy, lower fuel costs, and reduce emissions. Some characteristics of an EV are displayed in Figure 2 [3].

Every major automobile manufacturer now offers a variety of EVs for sale. Electric vehicles have the potential to reshape the transportation sector in the United States, drastically cutting carbon emissions and clearing the way for significant climate progress. As of now, millions of EVs are on the roads, and this number is expected to soar into the hundreds of millions in the coming decades. A total of 49 states, plus DC and Puerto Rico, took actions related to electric vehicles and charging infrastructure during 2023, as shown in Figure 3 [4].

Leading players including Hyundai Motor Company, Kia Corporation, General Motors, Tata Motors, Tesla Inc., and many others have heavily invested in the development of electric and hybrid vehicles. Manufacturers call upon logisticians to transport their electric vehicles. Electric vehicle transportation by train or truck is a major logistical step that starts when the cars come out of renowned manufacturers and finishes at the car dealers. The dealers either have their own garages or manage dealerships sponsored by the transported car brand. The fleets specific to electric vehicle transportation include trucks able to carry small or large quantities of vehicles. Some trains have car-carrier wagons which can transit via the freight network.

It is hard to credit a single person or nation with the development of the electric vehicles. The concept of EV has been around since the early years of the automotive industry. Around 1832, Robert Anderson developed the first crude electric vehicle, but it was not until the 1870s or later that electric cars became practical. Practical electric vehicles have been in use since the 1900s. After enjoying success at the beginning of the 20th century, the electric car began to lose its position in the automobile market. The discovery of petroleum led to the wide availability of affordable gasoline, making gasoline cars much cheaper and easier to operate. After years outside the limelight, the energy crises of the 1970s and 1980s brought about renewed interest in electric cars [5]. Due to the limitations of storage batteries at that time, electric cars did not gain much popularity, but electric trains became popular due to their economies and fast speeds. Many people believe that the debut of the Toyota Prius marked the beginning of a new era. The Prius was the first mass-produced hybrid electric car when it was introduced in Japan in 1997. You cannot talk about electric vehicles without mentioning Tesla/Elon Musk. Founded in 2003, Tesla has been a driving force in the adoption of high-performance electric vehicles. In 2006, the Silicon Valley Tesla Motors said it would begin manufacturing a high-end electric sports cars [6].

ELECTRIC VEHICLE COMPONENTS

Electric vehicles consist of various components, such as battery cells and packs, reducers, fuel stacks, power control units, power conditioners, air compressors, humidifiers, motors, on-board chargers, battery management systems, and others. Some of these components are illustrated in Figure 4 [7] and explained as follows [8]:

- *Battery Pack:* EVs rely on batteries as their source of power. The battery pack is the most essential and expensive component of EVs. Lithium batteries are often used in EVs due to their higher open circuit voltages and efficiency, longer cycle life, and lower self-discharge rate. When connected to the electric grid, EVs will absorb energy and store it; it can deliver electricity back to the grid if necessary. EV has the flexibility to integrate many different energy sources, such as tidal power, solar power, and wind power. To reduce the downtime required for charging EVs, wireless charging or wireless power transfer can be a smart solution. Figure 5 shows the battery of an EV [9].
- *Electric Motor:* The electric motor converts the energy from the battery into mechanical energy which enables the wheels to move. The motor converts electrical energy that it gets from the battery into mechanical energy There are various ways the electric motor is used the EV: a single motor, a motor in each wheels, a motor for each rear wheel, and one motor per wheel. Synchronous motors are commonly used in EVs due to their high efficiency and light weight. The efficient and reliable control of electric motors in EVs can become a major task.
- *Power Electronic*: This is an enabling technology for the development of EVs. Typical power electronic circuits used in EVs include rectifiers, inverters, and dc/dc converters. In addition, there is also a motor drive circuit for the air conditioner unit. A major challenge lies in obtaining low-cost inverter and the associated electronics for controlling a three-phase electric machine.

Introducing information and communication technologies in EV will improve energy efficiency and availability of charging stations, etc.

FACTORS AFFECTING EV ADOPTION

Electric cars have been growing in popularity in the last decade. There are many reasons to love having a car. Fortunately, electric vehicles are increasingly popular options for people who want to save money on gas and decrease their reliance on fossil fuels, but

still, need a car of their own. Electric vehicles are gaining popularity for the following ten reasons [10]:

1. Electric transportation is good for the environment
2. Electric transportation is going to be cheap in upcoming times
3. Electric vehicles are easy to maintain
4. No gas station or petrol pump is required
5. Electric transportation will provide a noise-free environment
6. Electric vehicles are soon going to become a status symbol
7. Electric transportation is saving non-renewable energy
8. Electric vehicles have the best user experience
9. Electric transportation can bring innovation
10. Now everyone can get a good range with electric transportation

There are three major factors affecting the deployment of electric vehicles: technology factors, policy factors, environmental factors [11].

- *Technology Factors:* These factors are related to characteristics of the EV, such as driving distance, charging time, and purchase price. In addition, other technology factors such as battery life, trunk space, top speed, are barriers for limiting consumer adoption.
- *Policy Factors*: Because EVs are relatively new, the government's support is a major factor for the initial market creation and full-scale diffusion of EVs. Many governments have implemented policies to encourage production and adoption of EVs. Many countries promote EVs by providing policy support such as purchase subsidies, public expenditure, tax reduction, government subsidy or tax benefit, tax exemption or tax exception, EV deployment target, free charging, and parking permissions.
- *Environmental Factors:* The environmental factors include fuel prices, consumer characteristics, availability of charging stations, etc. Fuel prices are the strongest predictors of EV adoption.

RELATED TECHNOLOGIES

Electric vehicles (EVs) have become increasingly popular over the past decade, offering a greener alternative to traditional petrol or diesel vehicles. They have gained significant attention in recent years due to their potential environmental benefits. They are quickly becoming a more popular and sustainable mode of transportation, thanks to reduced emissions, improved fuel efficiency, government incentives, advancements in technology, and increased availability of charging infrastructure. They depend on other related technologies such as charging, renewable energy, and power grid [12]:

- *Charging Stations:* Public charging stations are not as ubiquitous as gas stations. Charging equipment manufacturers, automakers, utilities, clean cities and Communities coalitions, states, municipalities, and government agencies are rapidly establishing a national network of public charging stations. Availability of charging stations at reasonable intervals, advances in rapid charging technology, and the development of more environmentally friendly means of generating the electricity needed to charge the cars all impact adaptability of EVs in the long run. Many businesses have begun installing charging stations ahead of the government's plans for a nationwide network. A charging station is shown in Figure 6 [6].
- *Renewable Energy*: Demand for energy is increasing with the mass adoption of electric vehicles, which requires strategic planning and efficient charging infrastructure. EVs can be powered by electricity generated from renewable energy sources. In response to several challenges, utilities, automakers, cities, and charging providers are offering pilot programs and rates designed to match EV loads with renewable energy. While the carbon footprint of EVs is influenced by electricity generation, advancements in renewable energy sources are steadily reducing this impact. Electric vehicles have great potential to draw down carbon emissions if widely adopted. They not only contribute to sustainable transportation but also have the potential to integrate seamlessly with renewable energy sources, forming a powerful synergy that can reshape our energy landscape. Moreover, electric vehicles offer a means of storing renewable energy generated from intermittent sources like solar and wind. Excess renewable energy can be stored in EV batteries and discharged when needed, enabling a more balanced and efficient integration of renewable sources into the grid.
- *Grid Capacity:* EVs are key players in the development of smart grids, where they can store and supply electricity, balance the grid, and support the integration of renewable energy sources like wind and solar power. Smart grids can manage where, when, and how much

electricity goes toward EV charging. Trading out a national fleet of gasoline-powered cars and trucks for a fleet of EVs means that millions of people will depend on the electric grid in new ways. Therefore, power generation capacity will need to increase to accommodate these vehicles without straining the grid. The Department of Energy predicts a 38 percent increase in electricity consumption by 2050, mostly due to a high penetration of electric vehicles.

APPLICATIONS OF ELECTRIC VEHICLES

The transportation and logistics industry has traditionally relied on trucks and trailers with internal combustion engines for domestic delivery purposes. In an era where sustainable solutions are becoming increasingly imperative, electric vehicles (EVs) are revolutionizing transportation and paving the way toward a greener future. The electrification of transport is a crucial step in the fight against climate change and the construction of a more resilient energy future. EVs are used in a variety of applications, including autonomous vehicles, electric bikes, electric scooters, public transportation, goods carrier, car relocation, etc. Common areas of application include the following [13]:

- *Autonomous Vehicles*: Autonomous or self-driving vehicles have the potential to revolutionize transportation, as they eliminate the need for human drivers, reducing the risk of accidents, and improving traffic flow. Self-driving cars could also be more efficient, as they can be programmed to take the most direct route and avoid congestion.
- *Electric Aircraft:* While electric planes are still in the experimental phase, some researchers are working on developing electric planes that can carry passengers. Electric planes have the potential to significantly reduce emissions from air travel, which is currently one of the most carbon-intensive forms of transportation.
- *Hyperloop:* The hyperloop is a proposed high-speed transportation system that involves sending pods through vacuum-sealed tubes at speeds of up to 700 miles per hour. The hyperloop has the potential to revolutionize transportation by reducing travel time and emissions, and some companies are already testing prototypes.
- *E-bikes and Scooters:* Electric bicycles, or e-bikes, are becoming increasingly popular as a sustainable alternative to cars for short trips. E-bikes are equipped with an electric motor that assists the rider, making it easier. Even electric cars were far rarer, more expensive and therefore less common than their fuel equivalents. This perception has significantly shifted in recent years, with electric cars, bikes, and scooters especially gaining huge amounts of popularity. Electric scooters feature restricted speed capabilities, which makes them highly suitable for use in urban areas where higher speed vehicles can pose significant risks. The small footprint of an e-scooter allows them to move through traffic far more effectively, resulting in less impact from congestion at peak times. Figure 7 shows an electric scooter [14].
- *Automotive Industry:* Car manufacturers have recognized the potential of electric vehicles and are committed to the transition to electric mobility. Some of the major manufacturers are devoting significant resources to the research and development of electric vehicles and related technologies. For example, Volkswagen, the German automotive giant, has announced ambitious plans to become a leader in electric vehicles. They are investing billions of euros in developing a full range of electric vehicles. General Motors, one of the largest automobile manufacturers in the United States, has announced that it aims to become a 100% electric company by 2035. They plan to invest in battery technologies and expand their electric vehicle offerings in the coming years.
- *Public Transportation:* The US transportation sector is at a pivotal tipping point. It is responsible for almost 30% of all greenhouse gas (GHG) emissions in the country, but it is also electrifying at an unprecedented rate. To truly combat the climate crisis, the US must shift its priorities and develop sustainable mass transit options. The deployment of electric vehicles (EVs) in transport fleets is a significant development. For example, electric cab services are garnering interest in Indian cities. A typical public transportation is shown in Figure 8 [15].
- *Goods Carrier:* Electric vehicles (EVs) can be used for goods transportation, including trucks, buses, and other commercial vehicles. Electric goods carrier designed for commercial logistic usage also in indoor environments, in small spaces or in areas where petrol vehicles cannot access. Such vehicles do not produce any pollutant or toxic gas when utilized. A typical goods carrier is shown in Figure 9 [16].
- *Electric Cars Relocation:* More and more people worldwide are showing interest in buying electric vehicles to help save the planet and reduce the environmental pollution caused by gas cars. If

you are traveling to a place that is far away or planning to relocate, it is better to have your car shipped than drive all the way there. Transporting your vehicle is a secure relocation method to reduce the chances of car accidents and avoid surprising weather conditions. Moreover, it saves the wear and tear of driving the car for a long time. Electric cars are more challenging to transport than their gas counterparts. And that is because they contain a lot of sensitive electronics and components that can easily be damaged in an accident. A truck for EV relocation is shown in Figure 10 [17].

- *Internet of Vehicles:* The Internet of vehicles which depends on EV is a network that consists of vehicles, humans, sensors, road infrastructure and charging stations. The Internet and smartphones enable a shift from ownership to car sharing model of transportation. Internet of vehicles (IoV) is essentially an application of Internet of things (IoT). When all the interconnected devices are vehicles, then IoT becomes Internet of vehicles (IoV), which provides information services, energy-saving emission reduction capability, and driving safety. IoV may be regarded as the evolution of conventional vehicle adhoc network (VANET), which is network that evolved from mobile ad hoc network (MANET). IoV promises great commercial benefits and research value. It will drastically enhance our lifestyles in the future and will boost the automobile market [18,19].

BENEFITS

Electric cars have several benefits over conventional gasoline automobiles. These include a significant reduction of local air pollution, more energy efficient and cheaper to fuel, zero emissions, environmentally friendly, and reduced energy dependence**.** They are much cheaper to buy today because of falling costs of battery costs. Electricity is ubiquitous and cheaper than gasoline in most parts of the world. EV eliminates many maintenance hassles such as oil changes. Other benefits include [20]:

- *Economic Benefits:* Operating an EV is generally cheaper than a conventional vehicle. With fewer moving parts, EVs require less maintenance, translating to lower long-term costs for owners. Additionally, the cost of electricity per mile is typically lower than that of gasoline. Reducing cost of ownership is important to build a robust economic case for deployment of electric vehicles. The integration of electric vehicles as energy storage resources also offers opportunities to optimize electricity utilization and improve system stability.
- *Sustainable Transportation:* Cities worldwide are actively embracing sustainable transportation solutions. As the world becomes more environmentally conscious, sustainable transportation is becoming an increasingly important issue. EVs produce zero tailpipe emissions, significantly reducing air pollution and greenhouse gases. As the electricity grid becomes greener with more renewable energy sources, the overall carbon footprint of EVs continues to diminish. By embracing sustainable transportation, we can reduce emissions and create a cleaner, healthier planet for future generations. The future of sustainable transportation holds even more exciting possibilities.
- *Reducing Cost of Li-ion Batteries:* Li-ion batteries are the most crucial component of electric vehicles. The reducing cost of batteries over the years has made EVs more affordable, pocket-friendly, and competitive with traditional internal combustion engine vehicles in the market.
- *Government Support:* Governments of various countries are promoting the adoption of electric vehicles by offering incentives and implementing policies, such as tax credits, rebates, grants, and regulations, that encourage automakers to produce electric vehicles. Federal and state incentives, combined with changing consumer preferences, have helped to boost sales of electric vehicles (EVs) in the United States at a time of growing concerns about climate change. Many governments offer incentives to encourage the adoption of EVs, with the aim of reducing air pollution and oil consumption. Government schemes have improved e-charging infrastructure, reduced tax on EV sales, and offered subsidies. Many countries have set the goal of banning the sales of combustion-powered vehicles in the near future. These include Norway, China, India, Germany, France, and Britain.
- *Lower Emissions:* The transportation sector is the largest source of greenhouse gas emissions in the United States. A successful transition to clean transportation will require various vehicle and fuel solutions and must consider life cycle emissions. Electric and hybrid vehicles can have significant emissions benefits over conventional vehicles. EVs can reduce carbon emissions by half or more compared to gasoline-powered cars. Electric vehicles have great potential to draw

down carbon emissions if widely adopted. Governments are imposing strict emission standards to reduce greenhouse gas emissions and combat climate change. Figure 11 shows a zero emission EV [9].

- *Efficiency:* EVs are two to three times more energy-efficient than conventional gasoline-powered vehicles and have no tailpipe emissions. EVs are more efficient at converting energy into propulsion than gasoline and diesel vehicles. Governments, school districts, businesses, and other large fleet owners can play a major role in supporting the transition to a zero-carbon transportation system by transitioning their own car, truck, and bus fleets to EVs.
- *Rural Communities:* In rural parts of the country, EVs can be an especially attractive alternative to conventional vehicles. Rural residents drive more than their urban counterparts, spend more on vehicle fuel and maintenance, and often have fewer alternatives to driving to meet their transportation needs. Over the long run, EVs will help residents of rural areas reduce those costs and minimize the environmental impact of transportation in their communities.
- *Improved Accessibility:* EVs can be designed with accessibility in mind, making them a better option for public transport. They can be fitted with ramps or lifts to make it easier for passengers with disabilities or mobility issues to board and exit the vehicle. In addition, EVs can be designed with wider doors and more space inside to accommodate passengers with prams, pushchairs, or luggage.
- *Public Health:* Electric cars, vans, trucks, and buses will play a key role in reducing some of the negative impacts of road transport on human health, the environment and climate. EVs produce no tailpipe emissions and are 67% less carbon intensive than gasoline-powered cars over their lifetime.
- *Job Creation:* Electric vehicles support over 300,000 American jobs, with new EV manufacturing poised to create hundreds of thousands of new jobs in the years to come. Enacting ambitious and realistic policies to accelerate transportation electrification will create hundreds of thousands of well-paying jobs. Congress must seize this opportunity or risk ceding this economic growth to others.

CHALLENGES

In spite the advances that electric vehicles have made, there are some barriers that stand in the way of widespread adoption. Electric vehicles have following disadvantages compared with conventional vehicles: recharging the battery takes time, driving range is typically short, number of charging stations is small, EV and batteries are expensive, and batteries can catch fire after a crash or mechanical failure. Some fear (or have range anxiety) that you run out of juice when you are nowhere near a charging station. The limited range of some EVs is a major challenge. Other challenges include the following [13]:

- *Higher Costs*: EVs can be more expensive to purchase than conventional vehicles. Electric cars generally have higher sticker prices than their gasoline-fueled counterparts, mostly because of expensive materials and processes used in battery production. Although energy costs for EVs are generally lower than for similar conventional vehicles, purchase prices can be significantly higher. Prices are likely to equalize with conventional vehicles, as production volumes increase and battery technologies continue to mature.
- *Need for Charging:* The functionality of these EVs depends on a wide range of factors, such as the availability of charging stations at reasonable intervals, advances in rapid charging technology, and the development of more environmentally friendly means of generating the electricity needed to charge the cars. The battery of electric vehicles needs to be charged frequently. Charging an electric car can be done at a variety of battery charging stations, which are much like gas/petrol stations. Car batteries are most often charged from the power grid overnight. Power sources such as photovoltaic solar cell panels or wind power may also be used. The range of the car depends on many factors such as the number and type of batteries used, the weight and type of vehicle, performance requirements, and the weather.
- *Lack of Charging Infrastructure:* The lack of charging infrastructure can limit the adoption of EVs. Rather than being refueled at a typical gas station, electric vehicles must be charged at electrical outlets in order to run. Many EV owners charge their cars at home in their garage using a special wall-mounted charger. However, for drivers who live in apartments, parking garages are rarely equipped with charging infrastructure, and installing such infrastructure may be cost prohibitive for building managers. An expanded charging infrastructure is needed for such EV owners.

- *Battery Longevity*: Over time, EV batteries degrade, resulting in a decreased capacity to hold a charge. This degradation can lead to reduced driving range and eventually necessitate costly battery replacements, adding to the total cost of ownership for EVs.
- *Material Sourcing:* EV batteries rely on raw materials, which can raise ethical and environmental concerns. Ensuring responsible sourcing and minimizing the environmental impact of battery production are essential considerations for the sustainable growth of the EV industry.
- *Pollution:* EV production is unsustainable. EV batteries are composed of several rare earth minerals, including cobalt and lithium. Mining companies expose nearby communities to high levels of toxins that are especially harmful to children. Although EVs do not directly emit fossil fuels, the energy generated to charge an EV predominately comes from fossil fuel power plants.
- *Customer Education:* This is a crucial component of creating a positive transition to electric vehicle adoption. Utilities can support education efforts by supplying EV ownership materials. This would include information on public charging, options for home and workplace charging, utility and local incentives for owning and leasing an EV, and relevant utility rates.
- *Equity Considerations:* Utilities can proactively incorporate equity frameworks into their planning and program processes, and they should prioritize historically overlooked and overburdened communities when designing programs. This includes supporting multi-unit dwelling charging infrastructure, creating incentives for low-income households, and ensuring that the benefits of EV adoption are accessible to all segments of society. Additionally, utilities can support public transit systems to help those dependent on public transportation, ensuring a more inclusive and equitable approach to electrifying transportation.

CONCLUSION

Electric vehicle is a promising way to reduce harmful greenhouse gas emissions. As a promising transportation tool, EVs are energy efficient, almost noiseless and pollution-free. Electric cars are already being embraced by environmentally conscious consumers, and as battery technology improves, electric cars are becoming more affordable and practical for the average consumer.

The rapid growth in electric vehicles (EVs) today is part of a fundamental shift in transportation that promises substantial benefits to individuals, businesses, communities, and the entire nation. The battery industry, the waste recycling industry, the charging infrastructure industry, the electric taxi industry, and many more will all see growth as a result of EV business growth.

Electric vehicles are seeing a rise in popularity today for many of the same reasons they were first popular. They hold a lot of potential for helping the US create a more sustainable future. There are several EV architectures in the market and there is no one-size-fits-all solution. The international sale of EVs is growing exponentially. It is expected that EVs will gradually penetrate the market in the next decade. EVs are the trend for future transportation. They signify a significant transition towards an environmentally friendly, sustainable, and cutting-edge future transportation system. As we stand on the brink of a transportation revolution, electric vehicles offer hope for a more sustainable future. More information about electric vehicles in transportation can be found in the books in [21-25].

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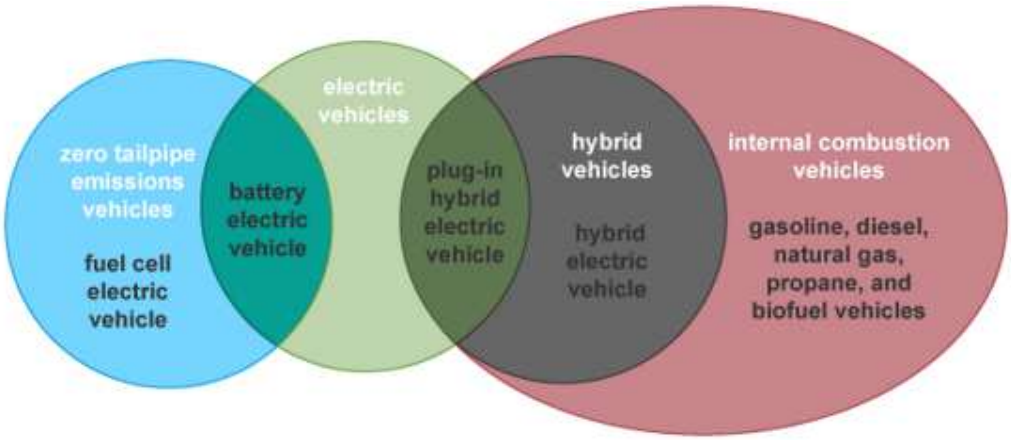

Figure 1 Vehicles by technology type [1].

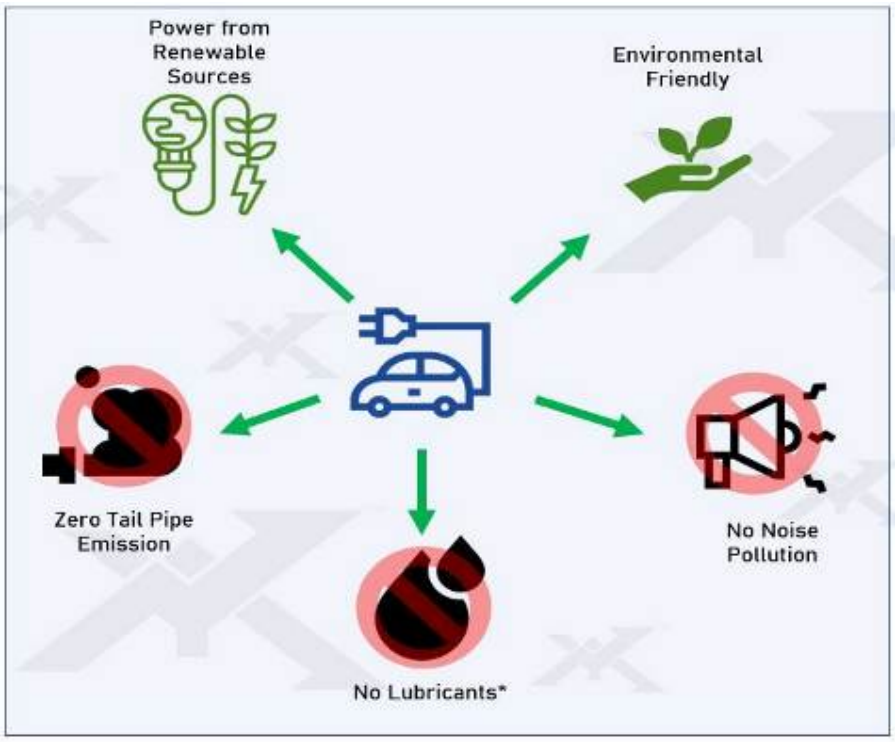

Figure 2 Some characteristics of an electric vehicle [3].

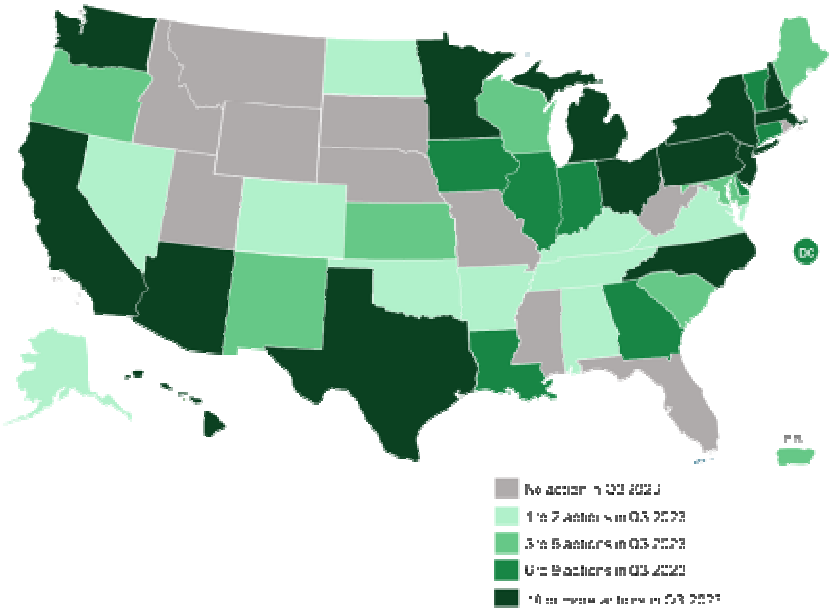

Figure 3 Charging infrastructure in the US during 2023 [4].

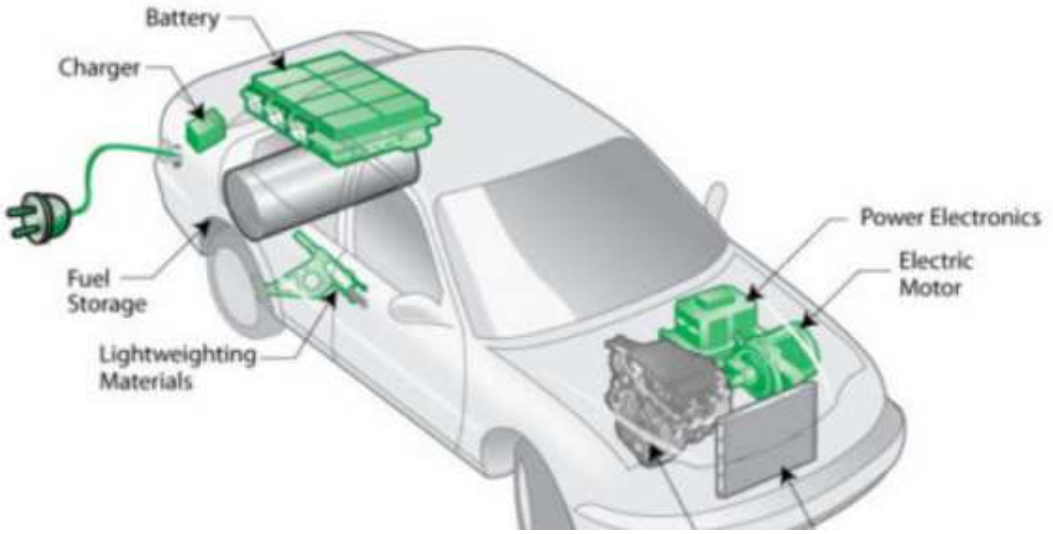

Figure 4 Components of an electric car [7].

Figure 5 Battery of an EV [9].

Figure 6 A charging station [6].

Figure 7 An electric scooter [14].

Figure 8 A typical public transportation [15].

Figure 9 A typical goods carrier [16].

Figure 10 A truck for EV relocation [17].

Figure 11 A zero emission EV [9].